MULTIPLE AND CASCADE PROCESSES PRODUCED BY ELECTRONS AND GAMMA-RAYS

BY

THEODORE ALLEN WELTON

B. S., Massachusetts Institute of Technology, 1939

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN PHYSICS
IN THE GRADUATE SCHOOL OF THE UNIVERSITY
OF ILLINOIS, 1943

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MULTIPLE AND CASCADE PROCESSES PRODUCED BY ELECTRONS AND GAMMA-RAYS

Quantum electrodynamics correctly predicts the possibilities of such radiation processes as bremstrahlung and pair-production. It also predicts less probable multiple processes, in which more than two final electrons or quanta result from a single particle incident upon a nucleus. Since the limits on the validity of quantum electrodynamics are not precisely known, it was thought to be of interest to calculate the probability of such a multiple process in the hope that an experimenal check might be possible.

The process chosen for study was that of double pair-production, in which a gamma-ray enters the coulomb field of a nucleus and creates two position-electron pairs. By the use of the methods of the perturbation theory of quantum electrodynamics, the probability of this process was estimated in a reasonable way. Because of the complexity of an exact calculation, a rough procedure giving good accuracy when applied to ordinary pair-production was used. The estimated cross-section for the process is:

$$\frac{1}{100} Z^2 \alpha^3 r_0^2 \log \frac{E}{8mc^2} \qquad (1)$$

Here Z is the atomic number of the nucleus, α is the fine-structure constant, r_0 is the classical electron radius, mc^2 is the rest energy of the electron, and E is the energy of the incident gamma-ray. This is a minimum but plausible estimate, smaller by a factor of one hundred than a conventional order of magnitude estimate would indicate.

The probability of a cascade process also yielding two pairs from a gamma-ray by successive pair-production and radiation processes was calculated, since such a process would be indistinguishable from the true double pair-production. A straightforward combination of the elementary probabilities

yields for the probability of this process in a thickness of t centimeters of lead for gamma-rays of twenty million volts energy:

$$0.1t^3 \quad (2)$$

The cross-section (1) yields for the corresponding probability of the multiple process approximately $10^{-7}t$. If these two probabilities are set equal, one obtains a critical thickness of 10^{-3} centimeters below which the multiple process would be more probable. With this thickness, the probability of the multiple process would be only about 10^{-10}, so that an experiment to observe the multiple process unambiguously would probably be impossible.

VITA

The author was born on July 4, 1918, in Saratoga Springs, New York, and completed his elementary and secondary education in the public schools of that city. He attended the Massachusetts Institute of Technology from 1935 to 1939, receiving the degree of Bachelor of Science in Physics in June of the latter year. In the fall of 1939, he entered the graduate school of the University of Illinois with an appointment as a research assistant on one-half time. He taught half-time during 1940 and 1941, and in 1942 received a third year fellowship for the completion of his work toward the Ph.D. degree.

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